

DIGITAL IMAGE MATCHING METHOD USING NORMALIZED CROSS-CORRELATION (NCC)

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Abstract

Digital image-matching techniques fall into three general categories: area-based, feature-based, and hybrid methods. In this experiment we use an area-based method that is Normalized Cross-Correlation (NCC) technique. In this approach, a statistical comparison is computed from digital numbers taken from same-size subarrays in the left and right images. The correlation coefficient can range from -1 to +1, with +1 indicating perfect correlation (exact match). a threshold value, such as 0.7, is chosen and if the correlation coefficient exceeds that value, the subarrays are assumed to match

The results present that using threshold=0.7, we can conclude that the similarity of two images using window size 3x3, 5x5, 7x7, 9x9 is 100%. But the similarity of two images using window size 11x11 is 70%. Then, using window size 3x3 and 5x5, we can achieve low RMSerror. It means that the different of position before and after NCC computation is not significant. However, using window size more than 8x8, RMSerror is so high more than 1 pixel.

The conclusions of this experiment are gaining larger window size, the correlation coefficient will be lower. It means that the similarity is low and the images are not exactly match. Then, the large of window size give more number of grey value so it give effect in computation of average, then it will make the position of new pixel moved. Getting larger window size so the movement will be so larger too, then the RMSerror will be high. And, the location of point will give contribution for the correlation coefficient. Because it will determine the varieties of pixel number

Introduction

Digital image-matching techniques fall into three general categories: area-based, feature-based, and hybrid methods. Area-based methods perform the image match by a numerical comparison of digital numbers in small subarrays from each image. Feature-based methods are more complicated and involve extraction of features, which are comprised of edges at different scales, with subsequent comparison based on feature characteristics such as size and shape. Feature-based image matching requires techniques from the realm of artificial intelligence in computer science. Hybrid methods involve some combination of the two first approaches.

Perhaps the simplest area-based digital image-matching method is a technique known as a normalized cross-correlation (NCC)

Normalized Cross-Correlation (NCC)

In this approach, a statistical comparison is computed from digital numbers taken from same-

size subarrays in the left and right images. A correlation coefficient is computed by the following equation, using digital numbers from subarray A and B

$$c = \frac{\sum_{i=1}^m \sum_{j=1}^n [(A_{ij} - \bar{A})(B_{ij} - \bar{B})]}{\sqrt{[\sum_{i=1}^m \sum_{j=1}^n (A_{ij} - \bar{A})^2][\sum_{i=1}^m \sum_{j=1}^n (B_{ij} - \bar{B})^2]}} \quad (\text{eq.1})$$

Where

- c = the correlation coefficient
- m and n = the numbers of rows and columns, respectively, in the subarrays
- A_{ij} = the digital number from subarray A at row i, column j
- \bar{A} = the average of all digital numbers in subarray A
- B_{ij} = the digital number from subarray B at row i, column j
- \bar{B} = the average of all digital numbers in subarray B

The correlation coefficient can range from -1 to +1, with +1 indicating perfect correlation (exact match). A coefficient of -1 indicates negative

correlation, which would occur if identical images from a photographic negative and positive were being compared. A coefficient value near 0 indicates a non match, and could result from comparison of any two sets of random numbers. Due to factors such as image noise, perfect (+1) correlation is extremely rare. Generally a threshold value, such as 0.7, is chosen and if the correlation coefficient exceeds that value, the subarrays are assumed to match.

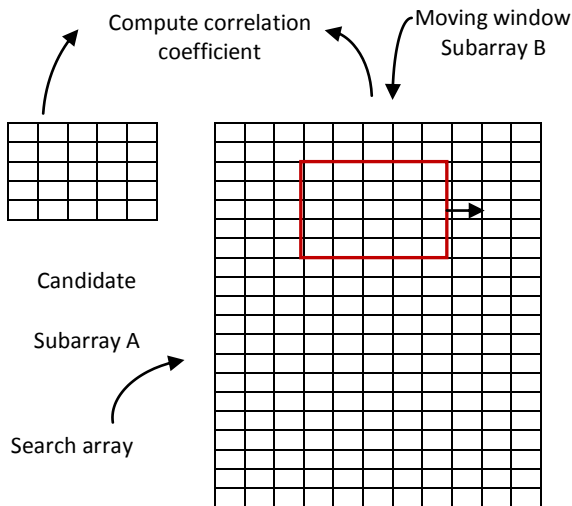


Figure1. Computing correlation coefficient using a moving window within a search array

Digital image matching by correlation can be performed in the following manner. A candidate subarray from the left photo is chosen, and a search will be performed for its corresponding subarray in the right image. Since the exact position of the image in the right image is not initially known, search array is selected with dimensions much larger than those of the candidate subarray. A moving window approach is then used, comparing the candidate subarray from the left image with all possible window locations within the search array from the right image as illustrated in Figure1. At each window location in the search array, the correlation coefficient is computed in a manner similar to moving window convolution, resulting in a correlation matrix C. After all coefficients have been computed, the largest correlation value in C is tested to see if it is above the threshold. If it exceeds the threshold, the corresponding location within the search array is considered to be match.

Methodology

- a. Data
 - 2 images cover NCU (National Central University) area
 - Image size: 11500 x 7500 pixels
 - Data format: Tiff



b. Flow Chart

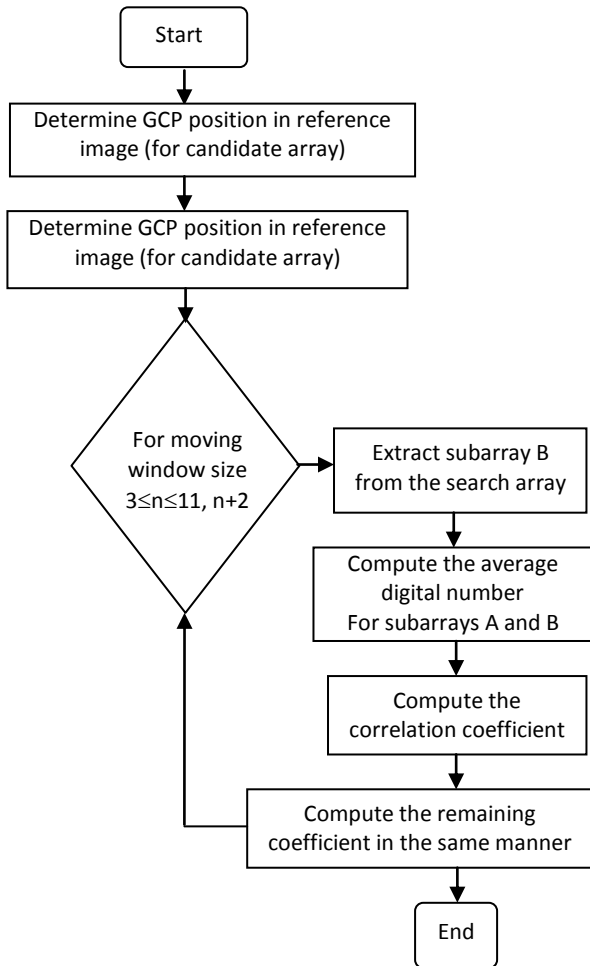


Figure2. Flowchart of Normalized Cross Correlation (NCC) computation

Experimental Result

a. Correlation Coefficients

Table1. The correlation coefficient in various window size

Correlation Coefficients in various window size					
	3	5	7	9	11
1	0.984	0.9	0.777	0.7	0.7
2	0.987	0.859	0.826	0.859	0.779
3	0.983	0.876	0.729	0.7	0.7
4	0.982	0.883	0.801	0.769	0.7
5	0.977	0.898	0.799	0.748	0.7
6	0.979	0.879	0.786	0.742	0.7
7	0.981	0.862	0.765	0.7	0.69
8	0.982	0.868	0.756	0.7	0.68
9	0.984	0.889	0.765	0.722	0.7
10	0.986	0.817	0.712	0.7	0.665

If we use threshold = 0.7. So we can compute similarity for each control point in several window sizes in this case 3, 5, 7, 9, and 11.

Table2. Similarity in percentage for several window sizes

Window size	Similarity in percentage (%)
3	100
5	100
7	100
9	100
11	70

Based on table1 and 2, we can know that:

1. Correlation coefficient for each control point in same window size is not significant different.
2. In window size 3 x 3 and 5 x 5, they have a high correlation coefficient. It assumes that the two images are exactly match.
3. Gaining larger window size, the correlation coefficient will be lower. It means that the similarity is low and the images are not exactly match. Because if the window size is larger, more numbers of pixel which are involved in search array. So, it will make effect in computation. However, the gray values that are involved are fully different. The result will be poor.
4. Using threshold=0.7, we can conclude that the similarity of two images using window size 3x3, 5x5, 7x7, 9x9 is 100%. But the similarity of two images using window size 11x11 is 70%.

b. RMS Error

After NCC computation, most of pixel location will change. It is because the position is settled suitable with the new position according the average of pixel value. Then because of movement, there is error that will be accounted by RMSerror.

The equation for RMSerror is

$$RMS\ error = \sqrt{\frac{\sum(V^T V)^2}{m - u}} = \sqrt{\frac{\sum(V^T V)^2}{r}}$$

Where, m is number of observation equations, u is number of parameters, so $r=m-u$ is redundant measurements or degrees of freedom.

The RMSerror of this experiment is presented in graphic below.

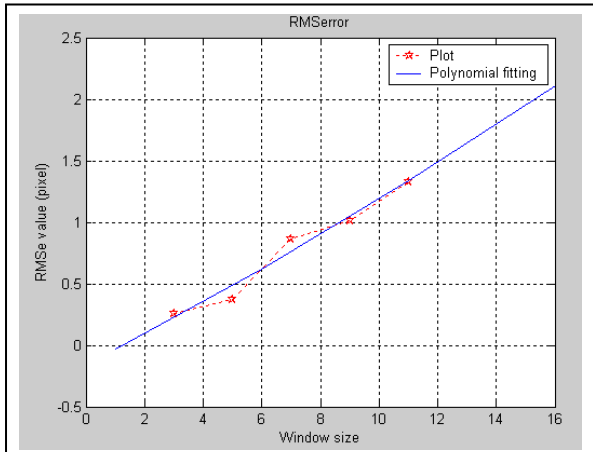


Figure3. RMSerror value vs window size

Based on graphic in figure2, we can know that:

1. Using window size 3x3 and 5x5, we can achieve low RMSerror. It means that the different of position before and after NCC computation is not significant.
2. Using window size 7x7, RMSerror is more than previous, but it still is less than 1 pixel.
3. However, using window size more than 8x8, RMSerror is so high more than 1 pixel. It means that if we want to do image matching in this case using NCC, we can use moving window less than 8x8 to get the good result.
4. The large of window size give more number of grey value so it give effect in computation of average, then it will make the position of new pixel moved. Getting larger window size so the movement will be so larger too, then the RMSerror will be high.

c. NCC Compare

According to NCC value in table1, we know that the most different of those is as below.

Correlation Coefficient in various window size					
	3	5	7	9	11
1	0.984	0.9	0.777	0.7	0.7
2	0.987	0.859	0.826	0.859	0.779
10	0.986	0.817	0.712	0.7	0.665

The location of control point number 1 is in the corner on the surface as in Figure3, the location of control point number 2 is on the roof as in Figure4, and the location of control point number 10 is on the grass land as in Figure5.



Figure4. Location of control point number 1



Figure5. Location of control point number 2

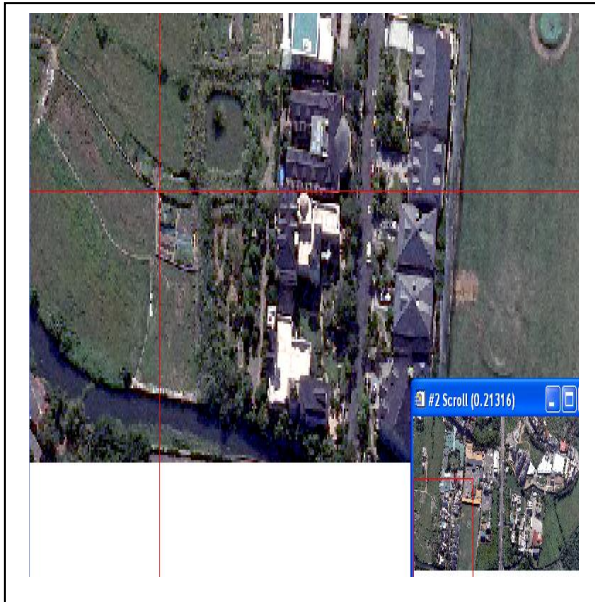


Figure6. Location of control point number 10

Based on the NCC value in table 1, we can know that:

1. The highest number of correlation coefficient is in number 2. Although the window size is 11 x 11, the correlation coefficient is more than the threshold. It is because the location of control point number 2 is on the roof that the distant between one roof and another is not so far. So the pixel number will be similar each other. It can match if we do image-matching. So the result of NCC is good.
2. The correlation coefficient of number 1 is less than number 2 but still more than number 10. It is because the location of number 1 is in the corner of the intersection, and the line of those is quite wide. So, if we use the small window size, the result of NCC will be high. However, if we use larger window size for example 11x11, the result will be so low, almost below the threshold.

3. The correlation coefficient of number 10 is less than threshold using window size 11x11. It means that it is not match. The location of number 10 is on the corner of intersection in the grass land. But the position is not clear because the line is not exactly straight. So, it will be difficult to pick the fix position.

Conclusions

Based on the experimental result, we can conclude:

1. Gaining larger window size, the correlation coefficient will be lower when the window size was 3x3 pixel, the correlation coefficient reaches around 0,9. It means that the similarity is low and the images are not exactly match
2. The large of window size give more number of grey value so it give effect in computation of average, then it will make the position of new pixel moved. Getting larger window size so the movement will be so larger too, then the RMSerror will be high. RMSerror was 1,4 pixel when the window size was 11x11.
3. The location of point will give contribution for the correlation coefficient. Because it will determine the varieties of pixel number.

References

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